Transport Policy 69 (2018) 132–140

Contents lists available at ScienceDirect

Transport Policy

journal homepage: www.elsevier.com/locate/tranpol

An alternative methodology for evaluating the service quality of urban taxis

R.C.P. Wong, W.Y. Szeto*

Department of Civil Engineering, The University of Hong Kong, Hong Kong

ARTICLE INFO

Keywords:
Level-of-service standard
Urban taxis
Customer satisfaction survey
Importance-satisfaction analysis
Enhanced linear regression model

ABSTRACT

This paper proposes an alternative methodology to evaluate the service quality of urban taxis and develops a level-of-service (LOS) standard for taxi customers to monitor performance. A customer satisfaction survey was conducted from January to March 2013 in Hong Kong, with the respondents invited to give specific satisfaction ratings for ten service aspects individually and a global satisfaction rating for the overall taxi service quality, as well as to rank the important aspects that influence the given global rating. The ten service aspects related to the amount of time consumed when taking taxis, services and facilities provided for finding taxis, internal environments of taxis, and personal services provided by taxi drivers. An enhanced linear regression model was developed to identify the priority areas for improvement of urban taxi service quality. Based on the numerical score of overall taxi service quality, a six-level LOS standard, similar to academic grading, is introduced accordingly to improve the general public's understanding of the current service level. This paper discusses the potential policy implications to enhance the taxi service quality in Hong Kong, which can be applied to other metropolitan cities that provide similar urban taxi services.

1. Introduction

Taxis continuously circulate in search of customers, which consumes a great deal of road space and worsens traffic congestion and air pollution. To tackle these problems, taxi regulation policies have often been studied and implemented in the form of price controls and entry restrictions (e.g., Arnott, 1996; Douglas, 1972; Moore and Balaker, 2006), but such studies have ignored the spatial structure of the taxi market. To address this issue, Yang and Wong (1998) first introduced a model to determine the taxi movements on a given road network. Later, the model was improved by other researchers to capture congestion effects, multiple user classes and taxi modes, day-to-day learning processes, stochastic travel time, temporal variation in passenger demand, time-dependent customer-search behavior, probability of meeting customers, and smartphone-based e-hailing applications (e.g., He and Shen, 2015; Leng et al., 2016; Long et al., 2017; Rose and Hensher, 2014; Wong and Yang, 1998; Wong et al., 2001, 2002; 2008, 2014a; 2014c, 2015a; Yang et al., 2005, 2012; 2014; Zhang et al., 2017). However, these models mainly investigate the vacant taxi drivers' decisions in search of customers while ignoring the customers' preference of finding vacant taxis on streets.

To study the bilateral taxi-customer meeting and searching, Wong et al. (2005) adopted absorbing Markov chain approach to modeling micro-searching behavior of both customers and taxi drivers in a network. Yang et al. (2010) further extended this study by incorporating a meeting function between customers and taxis to capture different meeting natures at taxi stands and on streets, and the searching decisions of customers and taxi drivers. Yang and Yang (2011) studied the bilateral searching and meeting function that characterizes the search frictions between vacant taxis and taxi customers. Wong et al. (2014b; 2015b) conducted stated-preference surveys to taxi drivers and customers, respectively, to investigate their search preferences to validate the modeling concepts.

Apart from the above surveys, annual taxi service surveys have been conducted in Hong Kong. The surveys have commenced since 1986 to gather quantitative measurements of customer and taxi waiting times, taxi utilization, and taxi availability at sampled taxi stands and roadside observation points (Transport Department, 1986–2009). These survey data have been used in numerous studies (e.g., Loo et al., 2007; Xu et al., 1999; Yang et al., 2000, 2001) to analyze how taxi fleet sizes influence customer waiting time (which was considered a unique measure of taxi service quality), vacant taxi headway, taxi occupancy, taxi passenger demand, and taxi idling time. They formulated the relationship between taxi fleet size and service quality, and arrived at a similar conclusion that taxi service quality increases as the taxi fleet size increases. However, taxis currently comprise a high proportion of the overall traffic stream in the urban area of Hong Kong and this situation occurs similarly at other metropolitan cities, such as Beijing and Taipei. A massive increase in the taxi fleet size may worsen traffic congestion, prolong taxi customers' in-vehicle traveling time and

* Corresponding author.
E-mail address: ceszeto@hku.hk (W.Y. Szeto).

https://doi.org/10.1016/j.tranpol.2018.05.016
Received 1 September 2017; Received in revised form 10 March 2018; Accepted 30 May 2018

adversely affect the service quality perceived by taxi customers. It is crucial to conduct a comprehensive study that measures customer satisfaction with urban taxi services and estimate appropriate taxi fleet size that achieves a minimum level-of-service (LOS) to taxi customers without causing serious traffic congestion.

Regarding the evaluation of LOS of public transport, Transportation Research Board of the National Academies (1999) prepared a handbook recommending methods to public transit agencies to identify the determinants of service quality from the customers' perspective. Other studies (e.g., Chiou and Chen, 2012; Correia et al., 2008; Das and Pandit, 2015; de Oña et al., 2016; Del Castillo and Benitez, 2013; Eboli and Mazzulla, 2011; Kurtulmuşoğlu et al., 2016; Lai and Chen, 2011; Lu and Chang, 2014; Tam et al., 2010) have also been carried out to evaluate the service quality of existing transportation systems and customer satisfaction. However, most efforts have focused on public transit modes rather than urban taxis. Different from the other public transit modes, taxis provide a tailor-made, point-to-point service to their customers, which have no fixed service frequency and routing. Taxi customers are not necessary to wait at a fixed location for the service, but have flexibility in finding a taxi in different ways (i.e., dispatching, street hailing, and waiting at taxi stands) (Schaller, 2007). The service natures of taxis are different from those of public transit, and hence suggestions for public transit on service enhancement cannot be applied directly to urban taxis.

Without a comprehensive study on customer perceptions on taxi service quality, the priority areas for improvements on taxi service quality cannot be identified. The government and taxi operators cannot effectively monitor the service performance and allocate their resources to make service improvements. To address this limitation, Yao and Ding (2011) firstly attempted to measure the quality of taxi services of Hangzhou, China. Follow up studies have been carried out (e.g., Li and Song, 2011; Dachyar and Rusydina, 2015; Techarattanased, 2015; Alonso et al., 2018) to evaluate the taxi service quality in some other cities. Most of these studies found that the variables related to driver behavior were highly valued by the customers, and significantly influenced their level of satisfaction. Recently, Shaaban and Kim (2016) calibrated a structural equation model for evaluating the taxi service quality in Doha, Qatar and hence provided suggestions to enhance the accessibility to taxi ranks. However, their study only interviewed the taxi customers who got taxis at taxi stands while neglecting those customers got taxis by taxi dispatching and street hailing. In fact, many cities have a mix of dispatch, stand, and street hail trips. For examples in the United States, San Francisco, and Boston have predominantly stand and hail trips; New York City represents an extreme case where its medallion cabs do not serve any dispatch trips and most of their trips are via street hail (Schaller, 2007). In Hong Kong, urban taxis mainly serve street hailing trips while few taxi customers find a vacant taxi by calling for a service and waiting at a taxi stand. Hence, this paper proposes an alternative methodology for evaluating the service quality perceived by a mix of dispatch, stand, and street hail customers and determining the service aspects that are most in need of improvement.

Most of the urban taxis in Hong Kong were private-owned, unlike other metropolitan cities where usually controlled by a limited number of operators. The taxi fare in Hong Kong was based on a non-linear fare structure with declining increments on the travel distance and waiting time. The taxi fare structure was the same throughout the day, without surcharges at night or during peak hours. In this study, we interviewed 1008 Hong Kong taxi customers at taxi stands and pedestrians on streets who had taken taxis recently, and invited them to state their levels of satisfaction with each of ten service aspects, the overall taxi service quality, and their rankings of the importance of these aspects. An enhanced linear regression model is developed and an importance-satisfaction analysis is conducted. A six-level LOS standard (using letters A through F, with A being the best and F being the worst, similar to academic grading) and its associated thresholds for urban taxi service quality are consequently proposed. The findings help identify the priorities of service quality improvements in terms of individual service aspects. The proposed LOS standard can be applied to evaluate the taxi service quality in Hong Kong and other metropolitan cities, and estimate the optimum taxi fleet size based on the predetermined policy target of minimum LOS to urban taxi customers.

This paper makes several contributions: (1) to the best of our knowledge, we are pioneers to introduce an LOS standard to monitor taxi service performance, (2) it proposes an alternative methodology to evaluate the service quality of urban taxis and identify the area of improvements, which has not been proposed by and used in other taxi service quality studies, and (3) it discusses novel and valuable policy insights to improve the taxi service quality in Hong Kong, as well as some cities that provide similar urban taxi services.

The remainder of this paper is structured as follows. Section 2 describes the details of data collection and performance evaluation survey. Section 3 presents the formulation of enhanced linear regression model and the score prediction curves for time-related quantitative service aspects, explains the results of the importance-satisfaction analysis, and gives a formula for determining the LOS score or equivalently the score of the overall taxi service quality. Section 4 illustrates the model results, suggests the priorities for taxi service quality improvements, and proposes an LOS standard and its associated thresholds. Section 5 recommends some policy implications. Finally, Section 6 concludes the paper.

2. Data

2.1. Data collection

A pilot survey was conducted about two weeks before the main survey, and about 50 taxi customers were interviewed to verify the feasibility of the survey approach and ensure the clarity of wording in the questionnaire. The main questionnaire survey was then conducted from January to March 2013 both during the day and at night. The face-to-face interviews took place in selected residential and commercial districts in Hong Kong. We randomly interviewed taxi customers at taxi stands and pedestrians on streets. The questionnaire survey would be ended and the data would be neglected from analysis if they had not taken urban taxis within the past three months. Besides the face-to-face interviews, the respondents were welcome to complete the questionnaire at home and mail back to us using an attached return envelope. In this study, we collected 1008 responses in total. About two third of the responses were collected on site during the face-to-face interviews, and the rest were collected by mail. The overall response rate was about 23%.

2.2. Performance evaluation survey

The questionnaire survey consists of two parts: 1) the demographic information of the urban taxi customers; and 2) satisfaction with the urban taxi services. Fig. 1 shows the questions for taxi customers' satisfaction level in the questionnaire survey. The respondents were invited to rate their levels of satisfaction with respect to ten selected service aspects and the overall urban taxi service according to their latest travel experiences of taking taxis. The satisfaction levels with individual service aspects were considered to be highly correlated to that of the overall service (Olawole and Aloba, 2014). The ten aspects spanned four categories and covered a wide spectrum including [1] time consumed when taking a taxi, [2] services and facilities for finding taxis, [3] internal environments, and [4] personal services provided by taxi drivers. In particular, [2] depends on how the customers search for taxis. Most of these aspects were found to be important in the previous studies (e.g., Yao and Ding, 2011; Li and Song, 2011; Alonso et al., 2018), and were verified in the pilot survey. The respondents could only evaluate a market-specific service aspect of either (d) the punctuality of called taxis *(if the customer got a taxi by taxi dispatching)*, (e)

Question B1: Please report your satisfaction level with urban taxi service based on your latest travel experience, and provide the actual time spent for taking a taxi and punctuality of taxi service:

		Dissatisfied 1	2	Neutral 3	4	Satisfied 5	No opinion/ Not applicable
[1]	**Time consumed when taking a taxi**						
	(a) Walking time required to take a taxi [Walking time: _____ minutes]	☐	☐	☐	☐	☐	☐
	(b) Waiting time required for a taxi [Waiting time: _____ minutes]	☐	☐	☐	☐	☐	☐
	(c) Time reaching its destination on time [Arrive _____ minutes earlier or later than the expected schedule]	☐	☐	☐	☐	☐	☐
[2]	**Services and facilities provided for finding taxis**						
	(d) The punctuality of called taxis [Arrive _____ minutes earlier or later than the expected schedule]	☐	☐	☐	☐	☐	☐
	(e) The difficulty of hailing taxis on streets *(i.e., excessive railings or stopping restriction zones along urban streets)*	☐	☐	☐	☐	☐	☐
	(f) Taxi stand facilities *(i.e., providing shelters, seats or directional signs to taxi stands)*	☐	☐	☐	☐	☐	☐
[3]	**Internal environments**						
	(g) Comfort level inside taxis *(i.e., offering comfortable indoor temperature and seats)*	☐	☐	☐	☐	☐	☐
[4]	**Personal services provided by taxi drivers**						
	(h) The attitudes of taxi drivers *(i.e., responding friendly and addressing customers' reasonable requests)*	☐	☐	☐	☐	☐	☐
	(i) The professionalism of taxi drivers *(i.e., having good driving skills and familiar with the road network)*	☐	☐	☐	☐	☐	☐
	(j) The ethical conduct of taxi drivers *(i.e., obeying traffic rules, taking the shortest path to destinations, and charging according to the fare meter)*	☐	☐	☐	☐	☐	☐
Overall satisfaction level with urban taxi service		☐	☐	☐	☐	☐	

Question B2: Please rank the above service aspects that influence your overall satisfaction level the most. If you have less than five aspects considered as important, you may leave the blankets blank.

Most important ___ 2nd important ___ 3rd important ___ 4th important ___ 5th important ___

Fig. 1. Questions for taxi customers' satisfaction level.

the difficulty of hailing taxis on streets *(if the customer got a taxi by street hailing)*, or (f) taxi stand facilities *(if the customer got a taxi by at a taxi stand)*.

The satisfaction level for each service aspect and the overall urban taxi service were recorded on the Likert five-point scale scoring system, with higher scores representing higher levels of satisfaction (i.e., 1 for very dissatisfied; 3 for neutral and having a passing score; and 5 for very satisfied). The respondents were allowed reporting "no opinion or not applicable" if they were not aware of the quality of an individual service aspect, or their latest travel experience did not involve that service aspect (e.g., respondents could not rate the punctuality of called taxis if they most recently hailed a vacant taxi on streets). To ensure the reliability of the collected data, the split-half method will be used to determine the degree of relationship between two sets of scores obtained for determining internal consistency.

The first two service aspects, (a) and (b), were related to the time spent getting into a taxi, and the following two service aspects, (c) and (d), were related to the punctuality of taxis whether reaching their destination and meeting pre-booked customers on time, respectively. These four aspects were time-related and hence quantitative. We additionally asked the respondents for the actual walking and waiting times for a taxi, and the actual arrival times ahead or behind their expected schedule on the latter two aspects of their latest travel experience (if any). If the respondents forgot the actual time spent in their latest experience of taking a taxi, we allowed them skipping this part, and no data from these respondents would be inputted for further analysis.

With the satisfaction level of each of the service aspects together with their importance, an importance-satisfaction analysis can then be conducted for prioritizing the improvement areas. The simplest approach is to obtain the importance by asking the respondents to rate each of the service aspects directly. However, some other customer satisfaction studies (Matzler et al., 2003; Abalo et al., 2007) criticized that the explicitly self-stated importance does not adequately measure the relative importance of service aspects. This approach may lead to the problem of crowding in the performance evaluation matrix and fail to distinguish which service aspects are most in need of improvement. In this study, we invited the taxi customers to rank the most important

aspects (five at most) that influenced their overall satisfaction level. The number of important aspects could be less than five and different between the respondents. Various researches have adopted a similar survey approach and agreed that the top five important aspects most frequently listed by the respondents could be used as surrogates to measure importance (Sampson and Showalter, 1999; Matzler et al., 2003). In addition, asking respondents to rank service aspects in order of importance rather than assigning them absolute importance values provides a relative or competitive measure of importance for each aspect and allows a higher degree of respondents' involvements in the evaluation task.

3. Method

3.1. Explicitly self-stated and implicitly derived importance

In this study, we adopted three methods to measure both the explicitly self-stated and implicitly derived importance of each of the service aspects. First, we used a partial ranking method to determine the percentage of interviewed taxi customers listing each of the service aspects in the top five. Then, we used a mean ranking method, giving a score of 5 to the top-ranked aspect and 1 to the fifth-ranked to calculate the mean of ranks, and assigning a score of 0 to all aspects not mentioned by the respondents. Third, as a form of implicitly derived importance, we calibrated model coefficients as importance weights by correlating individual service aspects' satisfaction levels with overall satisfaction level. Numerous researches have attempted modeling the importance weights based on the overall satisfaction (e.g., Del Castillo and Benitez, 2013; Chen and Chen, 2014). Later, Abalo et al. (2007) initiated an alternative assessment of importance to improve the conventional method by subjecting appropriately scaled mean ranks to a transformation that depends on the proportion of ranked aspects and the reported orders. The findings showed that it achieves the desired spread of aspects in the performance evaluation matrix, thereby improving the readability and utility of this tool for successful market planning. However, their study predefined a decaying trend of importance and assumed a top ranking service aspect having a fixed and larger effect on the overall satisfaction level without any empirical support. Furthermore, it forced the respondents to rank only the top three important aspects, which did not allow the respondents deciding the number of service aspects that they considered important. In this study, we reformulate the model and release both of these constraints, in which the proportion of importance according to the reported orders is determined by the proposed model and the number of important aspects is not restricted and can be different among the respondents.

3.2. Enhanced linear regression model

We propose an enhanced linear regression model to investigate the importance of each of the service aspects to the overall satisfaction level of the urban taxi service, which takes the following form

$$\hat{S}_n = \sum_{q \in Q} [P(R_n^q|V_n)\theta^q] S_n^q, \tag{1}$$

where $\hat{S}_n$ denotes the satisfaction level of the overall service quality for taxi customer n, which expresses in a numerical score. Q denotes the set of service aspects, where $Q = \{(a), (b), ..., (j)\}$. S_n^q denotes the individual satisfaction score of service aspect q for taxi customer n. θ^q denotes the model coefficient associated with the individual service aspect q for fitting the overall satisfaction score, which is assumed to be the same for all taxi customers in regression modeling. $P(R_n^q|V_n)$ denotes the proportion of the satisfaction score of service aspect q contributing to the overall satisfaction score. It depends on the rank of service aspect q (R_n^q) and the number of important aspects (V_n) considered by taxi customer n. Both R_n^q and V_n are integers and $1 \le R_n^q \le V_n \le 5$. If the service aspect poses a higher rank of importance, its corresponding satisfaction score contributes to a higher proportion of the overall satisfaction score of taxi service quality. The proportion is constrained by $P(R_n^q|V_n) \ge P(\min[R_n^q + 1, V_n]|V_n)$, $0 \le P(R_n^q|V_n) \le 1$ and $\sum_{R_n^q=1}^{V_n} P(R_n^q|V_n) = 1$. It introduces non-negative and non-zero weightings to the important aspects listed by respondent n and allocates zero to the rest of the aspects. For example, if the taxi customer n considers only two service aspects are important (i.e., $V_n = 2$) while ranking aspect (a) as the most important (i.e., $R_n^{(a)} = 1$) and aspect (b) as the second important (i.e., $R_n^{(b)} = 2$), then $P(R_n^{(a)}|V_n) = P(1|2)$, $P(R_n^{(b)}|V_n) = P(2|2)$, $P(1|2) \ge P(2|2)$, $P(1|2) \ge 0$, $P(2|2) \ge 0$, and $P(1|2) + P(2|2) = 1$.

In sum, $\hat{S}_n$, S_n^q, R_n^q, and V_n were collected from the taxi customer n during the face-to-face interview, θ^q and $P(R_n^q|V_n)$ are estimated simultaneously in the enhanced linear regression model based on the least squares method.

3.3. Score prediction curves for time-related quantitative service aspects

To supplement the above enhanced linear regression model, score prediction curves are proposed for the relationship solely between the perceived scores of the four time-related quantitative service aspects and the corresponding reported time spent by the interviewed taxi customers. The prediction curves can then be used to estimate the changes in the individual scores of these four service aspects according to the variations in time spent for a taxi, and are mathematically expressed as

$$S_n^q = \begin{cases} 4\exp(\mu^q T_n^q) + 1 & \text{, if } q = (a) \text{ or } (b); \\ \frac{4}{1+\alpha^q \exp(\beta^q T_n^q)} + 1 & \text{, if } q = (c) \text{ or } (d), \end{cases} \tag{2}$$

where T_n^q is the time spent associated with service aspect q for individual n, μ^q refers to the coefficient associated with the walking or waiting time, and α^q and β^q are the coefficients associated with the punctualities of a taxi of reaching its destination or meeting the pre-booked customer on time.

An exponential decay curve is proposed for the relationship between the time spent and the satisfaction scores of service aspects (a) walking time required to take a taxi, and (b) waiting time required for a taxi, as shown in the upper part of Equation (2). The values of T_n^q are non-negative in both of these cases. The proposed exponential decay curve presumed that the perceived scores reach their maximum of five when the time spent equals zero, and decreases when the time spent increases. The scores are bounded by a lower limit of one.

A generalized logistic curve is proposed for the relationship between the punctuality of taxis and the perceived scores of service aspects (c) taxi reaching its destination on time, and (d) the punctuality of called taxis, as shown in the lower part of Equation (2). It is important to clarify that a negative T_n^q value represents time-saving and a positive T_n^q value represents a delay in taxi arrival time. According to the proposed generalized logistic curve, the perceived scores are firstly peak at five when there is a large-scale of time-saving, gradually decrease, and finally tend to their minimum of one when the delay approaches infinity.

The above prediction curves reasonably reflect the overall scoring criterion of taxi customers although taxi customers may have different perceptions of time spent (i.e., different values of time) and their own satisfaction level on the urban taxi services could be different. All the curve-fitting coefficients are estimated using the least squares method.

3.4. Importance-satisfaction analysis

To rank the priorities of improvement plans for dissatisfied service aspects of urban taxis, an importance-satisfaction analysis was carried out to provide a quick visual representation of service satisfaction and importance ratings. The (average) service satisfaction and the (average) derived importance ratings of service aspects q indicating in the performance evaluation matrix are calculated as $\frac{1}{N}\sum_{n=1}^{N} S_n^q$ and

$\frac{1}{N}\sum_{n=1}^{N} P(R_n^q|V_n)\partial^q$ respectively, where N denotes the sample size. Taxi companies, taxi drivers, and policymakers can establish strategies accordingly that better address the target customers' needs and direct investments toward the most effective enhancements. Lambert and Sharma (1990) initiated the concept of the performance evaluation matrix and this analysis tool has been adopted extensively on service quality evaluation (e.g., Hung et al., 2003; Chen et al., 2007; Wong et al., 2017). The performance evaluation matrix is divided into nine performance cells. The service aspects with a relatively high importance and low satisfaction are considered most in need of improvement. Conversely, for those with a low importance and high satisfaction, no immediate improvement is needed and continuous monitoring is suggested. The service aspects with moderate importance and satisfaction are recommended to be maintained their service quality to prevent deterioration or improved if resources allow.

3.5. Level-of-service score

The sum of the product of the satisfaction score of each service aspect multiplying by the corresponding importance weighting gives the overall service satisfaction score (equivalent to the numerical score of LOS) of urban taxis, which is mathematically expressed as

$$\text{LOS score} = \sum_{q\in Q}\left[\frac{1}{N}\sum_{n=1}^{N} P(R_n^q|V_n)\partial^q\right]\left[\frac{1}{N}\sum_{n=1}^{N} S_n^q\right]. \quad (3)$$

4. Results and discussion

4.1. Demographical distribution of interviewed taxi customers

Fig. 2 shows the demographical distribution of the interviewed taxi customers. It is noted that the samples were collected approximately evenly from male and female. Most of them were in a younger age group of 22–34. About 61% of the respondents had a full-time job. The majority of the respondents reported that they were educated up to the tertiary level or above. We categorized their income level into five groups, in which more than 60% of the respondents had a monthly income higher than HK$10,000. The findings demonstrate the demographical characteristics of taxi customers, who were usually younger, with a higher income and education level.

4.2. Satisfaction score and rank of service aspects

Table 1 shows the satisfaction score and rank of each of the service aspects. It is noticed that most of the service aspects performed well and received scores higher than the passing score of three, except (e) the difficulty of hailing taxis on streets. As reflected by the respondents during the survey, some taxi drivers refused to pick up a customer who was heading to a congested area or having a short journey, and many roads did not allow for picking up and dropping off customers. In contrast, the respondents gave the highest score of 3.71 to (c) taxi reaching its destination on time, followed by (a) walking time required to take a taxi and (j) the ethical conduct of taxi drivers. The respondents were satisfied the overall service quality of urban taxi services and gave a satisfaction score of 3.48.

Table 1
Satisfaction and rank of service aspects.

Service Aspects	Satisfaction		
	Mean Score	Standard Deviation	Rank
(a) Walking time required to take a taxi	3.61	0.86	2
(b) Waiting time required for a taxi	3.41	1.01	8
(c) Taxi reaching its destination on time	3.71	0.85	1
(d) The punctuality of called taxis	3.50	0.99	5
(e) The difficulty of hailing taxis on streets	2.90	1.05	10
(f) Taxi stand facilities	3.03	0.91	9
(g) Comfort level inside taxis	3.48	0.76	6
(h) The attitudes of taxi drivers	3.44	0.79	7
(i) The professionalism of taxi drivers	3.51	0.77	4
(j) The ethical conduct of taxi drivers	3.56	0.82	3

4.3. Self-stated importance and rank of service aspects

In addition to the satisfaction level of the each of the service aspect, two forms of customers' self-stated importance (partial ranking and mean ranking) are provided in Table 2. Using partial ranking, there were more than 61% of the respondents considering (h) the attitudes of taxi drivers, as one of their five most important aspects. On the other hand, about 90% of them agreed that (d) the punctuality of called taxis or (f) taxi stand facilities were not important to them. This result is considered reasonable because the taxi market in Hong Kong is highly concentrated in the street hailing market, and most of the taxi customers find a vacant taxi by searching on streets. Alternatively, using mean ranking, the mean of ranks are calculated. It is noted that only minor differences occur between the rankings. The Spearman-rho rank order correlation coefficient is 0.952.

4.4. Model results

Table 3 shows the optimal allocation of the proportion of the satisfaction score of individual service aspects contributing to the overall score of service quality. In instances where a respondent considers only one service aspect important, the satisfaction score of the single aspect reasonably contributes 100% to the overall service quality score. If the number of important aspects considered by a taxi customer is more than one, the listed service aspects are expected to share the proportion subject to their ranks. For example, in the case when two aspects are considered important, the top-ranked aspect is expected to give a higher contribution to the overall score than the following ranked aspect. According to our calibration results tabulated below, 54% goes to the

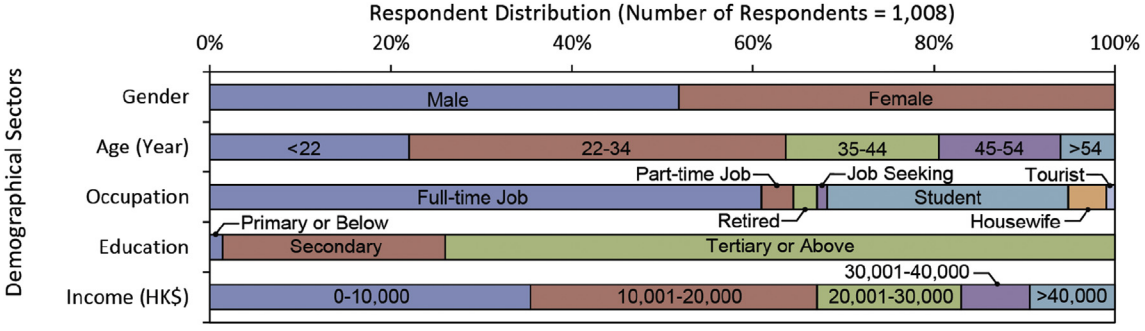

Fig. 2. Demographical distribution of the interviewed taxi customers.

Table 2
Self-stated importance and rank of service aspects using partial and mean rankings.

Service Aspects	Importance			
	Partial Ranking		Mean Ranking	
	Percentage listed in Top 5	Rank	In Top 5[a]	Rank
(a) Walking time required to take a taxi	25.30	8	0.77	7
(b) Waiting time required for a taxi	54.46	4	2.07	2
(c) Taxi reaching its destination on time	44.35	5	1.56	5
(d) The punctuality of called taxis	8.93	10	0.26	10
(e) The difficulty of hailing taxis on streets	32.94	6	1.07	6
(f) Taxi stand facilities	10.62	9	0.27	9
(g) Comfort level inside taxis	26.88	7	0.67	8
(h) The attitudes of taxi drivers	61.01	1	2.15	1
(i) The professionalism of taxi drivers	56.15	2	1.89	3
(j) The ethical conduct of taxi drivers	56.05	3	1.86	4

Notes: [a] 1st rank = 5 and 5th rank = 1.

Table 3
Estimated proportion of individual score of service aspects according to rank order contribute to the overall satisfaction score.

Rankings	Number of Important Aspects Considered				
	1	2	3	4	5
1 (Most important)	1.00	0.54	0.34	0.33	0.21
2		0.46	0.33	0.23	0.21
3			0.33	0.22	0.21
4	Not applicable			0.22	0.21
5 (Least important)					0.16

top-ranked service aspect and the remaining 46% goes to the following ranked aspect.

Table 4 presents the coefficient of each service aspects in the enhanced linear regression model. All of the coefficients are positive and significant at the 1% level, which implies that all the listed important aspects significantly affect the overall service satisfaction score given by taxi customers. A service aspect with a higher coefficient magnitude indicates that it has a higher influence on the overall service performance. In particular, service aspects (f) taxi stand facilities, (e) the difficulty of hailing taxis on streets and (i) the professionalism of taxi drivers have the larger coefficients than the others. Accordingly, the average derived importance scores are calculated and the associated ranks are provided.

In order to test the difference between explicitly self-stated and implicitly derived importance, a comparison was conducted which shows that the ranks of average derived importance rating and those of the partial and mean rankings had a strong correlation. The Spearman-rho correlation coefficient between the aspect ranking derived from the proposed model with the ranks based on partial ranking is 0.976, and with the ranks based on the mean ranking is 0.988. The results demonstrate that the derived importance is reasonable to rank the important aspects and reflect the actual perception of taxi customers.

Fig. 3 illustrates the score prediction curves for the four time-related service aspects and Table 5 presents the associated curve-fitting coefficients. The coefficients for both (a) walking time required to take a taxi ($\mu^{(a)}$) and (b) waiting time required for a taxi ($\mu^{(b)}$) are the same (-0.11). This illustrates that the respondents' perceptions of walking and waiting were identical. Based on the curves in the upper part of Fig. 3, we found that the respondents are satisfied (i.e., they give a passing score of three) when the walking or waiting time equals 6.30 min. For the prediction curve for service aspect (c) taxi reaching its destination on time, the associated coefficients of $\alpha^{(c)}$ and $\beta^{(c)}$ are 0.51 and 0.09, respectively. This implies that the respondents are satisfied when the delay in arrival time is 7.48 min. The curve-fitting coefficients ($\alpha^{(d)}$ and $\beta^{(d)}$) for (d) the punctuality of called taxis are 0.57 and 0.15, respectively. This demonstrates that the taxi drivers have to arrive no more than 3.75 min late to obtain a passing score of three. To sum up, the taxi customers are more accepting the situations in which they reached their destinations slightly behind schedule than the situations in which a called taxi arrived late.

4.5. Recommended priorities of taxi service quality improvements

Fig. 4 demonstrates the performance evaluation matrix. The x-axis is for service performance rating and the y-axis is importance ranting. The figure also indicates the average satisfaction rating and average importance rating of each of the service aspects in the two-dimensional space. The two vertical lines in the middle of the figure cut the x-axis at the values of 3.161 and 3.669 equal the average service performance rating of the ten service aspects (3.415) plus and minus one standard deviation of 0.254, respectively. Likewise, the two horizontal lines cut at the values of 0.044 and 0.156 equal the mean value of the importance rating of the ten service aspects (0.100) plus and minus one standard deviation of 0.056, respectively.

The service aspects (in the red cells on the top-left corner) requiring immediate attention and having the highest priority for service quality improvements include (e) the difficulty of hailing taxis on streets (with the lowest satisfaction level as reported by the respondents), (b) waiting time required for a taxi, (h) the attitude of taxi drivers, and (i) the professionalism of taxi drivers. The latter three aspects were identified to be the most important among all the service aspects. On the other hand, (c) taxi reaching its destination on time, and (d) the punctuality of called taxis fall in the green cells on the bottom-right corner. The model suggests that they have the lowest priority for improvement

Table 4
Estimated coefficients for the enhanced linear regression model.

Service Aspect	Coefficient[a]	t-statistics	Average Derived Importance Score	Rank
(a) Walking time required to take a taxi	1.03	23.9	0.06	7
(b) Waiting time required for a taxi	0.97	43.5	0.16	3
(c) Taxi reaching its destination on time	0.98	36.2	0.11	5
(d) The punctuality of called taxis	0.99	15.6	0.02	10
(e) The difficulty of hailing taxis on streets	1.10	26.7	0.09	6
(f) Taxi stand facilities	1.13	18.1	0.03	9
(g) Comfort level inside taxis	0.94	18.5	0.06	8
(h) The attitudes of taxi drivers	1.03	38.2	0.17	1
(i) The professionalism of taxi drivers	1.07	35.0	0.16	2
(j) The ethical conduct of taxi drivers	0.98	31.8	0.14	4

Notes: [a] All of the parameters are significant at the 1% level.

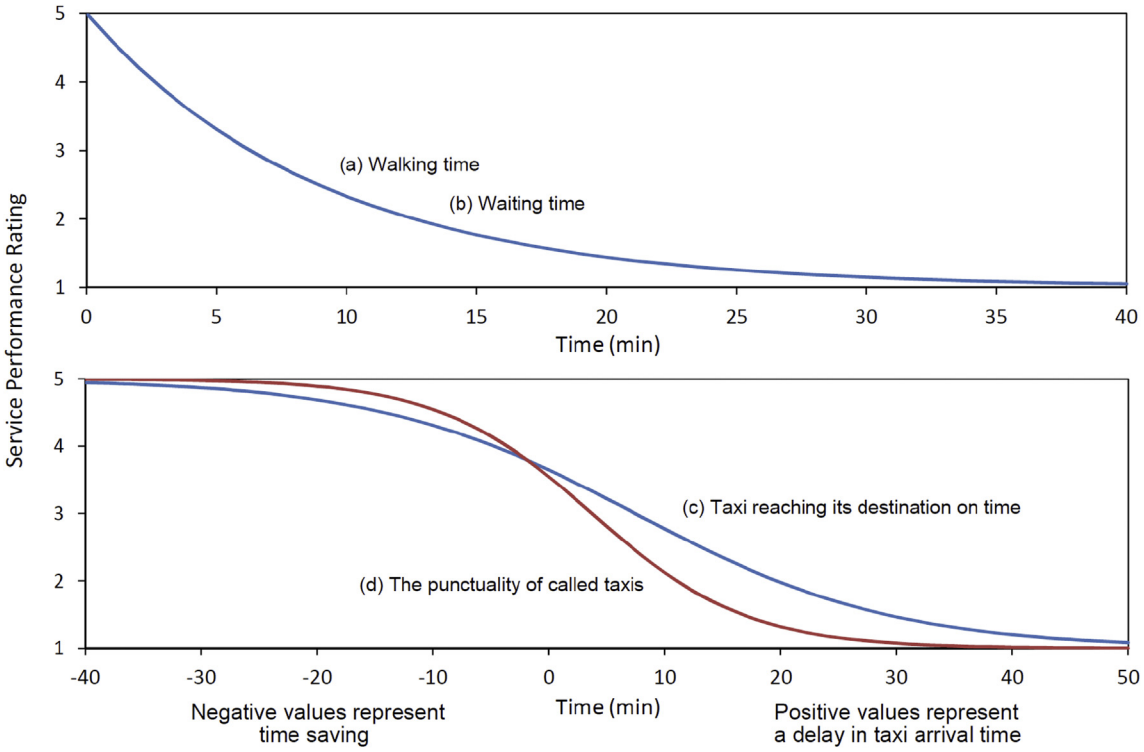

Fig. 3. Score prediction curves for time-related service aspects.

Table 5
Curve-fitting coefficients of score prediction curves.

Service Aspects	Coefficients
(a) Walking time required to take a taxi	$\mu^{(a)} = -0.11$
(b) Waiting time required for a taxi	$\mu^{(b)} = -0.11$
(c) Taxi reaching its destination on time	$\alpha^{(c)} = 0.51$; $\beta^{(c)} = 0.09$
(d) The punctuality of called taxis	$\alpha^{(d)} = 0.57$; $\beta^{(d)} = 0.15$

because they are listed as the best performed and least important aspect, respectively. The remaining four service aspects (in the white cells), including (a) walking time required to take a taxi, (f) taxi stand facilities, (g) comfort level inside taxis, and (j) the ethical conduct of taxi drivers are recommended to be maintained their service quality to prevent deterioration or improved if resources allow.

4.6. Proposed level-of-service thresholds

The overall satisfaction score of urban taxi services (equivalent to the numerical score of LOS) is 3.45 as calculated by applying Equation (3), which is close to the average score directly reported by the respondents (3.48). It implies that the proposed enhanced linear regression model accurately reflects the perceived satisfaction levels of taxi customers. To better present the taxi service quality to the general public, we propose using a threshold scheme to convert the numerical score to a letter grade. Table 6 tabulates a suggested LOS threshold scheme, in which the service quality is ranked according to a six-letter scale from A to F. A represents the best service quality and F represents the worst. The proposed threshold scheme offers a compressed range (0.6) for the B to E grades and reserves a wider range (0.8) for the A and F grades. Otherwise, a few dissenters could easily influence the overall result to drag the mean LOS from A or F to other grades, and A or F grade would be much harder to achieve unless all the respondents agreed the LOS falling in these extreme grades (Transportation Research Board, 2008).

According to the average scores of the service aspects stipulated in Table 1, most of the service aspects are ranked at a grade of C, except (a) walking time required to take a taxi and (c) taxi reaching its destination on time ranking at a grade of B, and (e) the difficulty of hailing taxis on streets ranking at a grade of D. Both the overall satisfaction scores of urban taxi service quality collected (3.48) and calculated (3.45) receive a grade of C, implying the current taxi service in Hong Kong is average. In addition, we can update the LOS numerical score by updating the individual satisfaction scores of the four time-dependent quantitative service aspects based on Equations (2) and (3). The time spent for taxi services are likely affected by taxi availability, passenger demand, and the traffic congestion level in the road network. They are controlled by policymakers and can be obtained by observational surveys on sites. For the other subjective service aspects, most of them are controlled by the taxi companies and drivers. We recommend reviewing their satisfaction level periodically by conducting customer satisfaction surveys to update the taxi customers' perceptions.

5. Policy implications

According to the performance evaluation matrix, four service aspects are identified for immediate improvements. The difficulty of hailing taxis on streets has the lowest satisfaction level as reported by the respondents. They complained that some taxi drivers refused to pick up a customer who was heading to a congested area or having a short journey, and many roads did not allow for picking up and dropping off customers. To improve the service quality, the government should take appropriate enforcement actions against hire refusal. Furthermore, it is suggested to issue restricted zone permits to taxi drivers and allow them picking up and dropping off customers for a better point-to-point service. The implementation situation of this relaxation scheme should be closely monitored to ensure the taxi drivers obeying the "no-waiting" rule and not causing obstruction to other road users.

Waiting time for a taxi is particularly long during rush hours. The straight-forward solution is to increase taxi supply, but it may further worsen the traffic congestion problem. Alternatively, the government

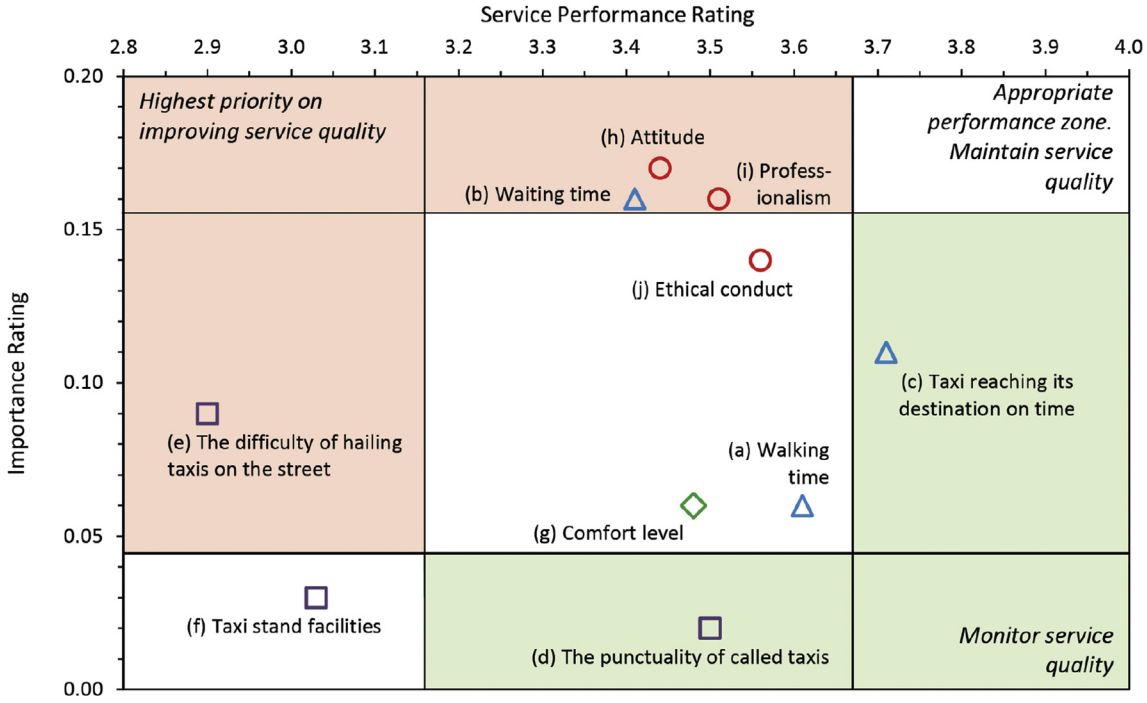

Fig. 4. Recommended priorities for taxi service quality improvements.

Table 6
Proposed level-of-service thresholds.

LOS Grade	A	B	C	D	E	F
Definition	Excellent	Good	Average	Poor	Very Poor	Failing
Overall satisfaction score	$\hat{S} > 4.2$	$3.6 < \hat{S} \leq 4.2$	$3.0 < \hat{S} \leq 3.6$	$2.4 < \hat{S} \leq 3.0$	$1.8 < \hat{S} \leq 2.4$	$\hat{S} \leq 1.8$

may consider suppressing passenger demand by introducing a peak hour surcharge and enhancing the service quality of other public transport modes. It has been proved effective to the taxi market in Singapore.

The attitude and professionalism of taxi drivers are the other two aspects needed to be improved. As most of the urban taxis in Hong Kong are private-owned, it is more difficult to manage and control the service performance of these taxis compared to those controlled by a limited number of operators. In order to encourage the taxi trade to improve the quality of taxi services, the government launched a taxi driver commendation scheme to give commendation to those taxi drivers with good conduct and quality performance, produced a taxi operation self-learning video programme for taxi drivers to enhance the service standard, and published a guidebook to describe the obligations and conduct of drivers. Besides the existing efforts, the government is recommended to explore the possibility of introducing luxury taxis to serve the passengers with a higher expectation of taxi service quality.

In addition to the applications of the performance evaluation matrix, the proposed LOS standard for taxi customers can be applied indirectly to determine the taxi fleet size appropriate for offering reasonable service quality to taxi customers. For example, if the target of taxi service quality to taxi customers is predetermined as LOS grade B (i.e., providing a good service), the government may consider increasing the taxi fleet size to a certain level in order to decrease the walking time and waiting time for customers finding a taxi. However, a massive increase in the taxi fleet size may, on the other hand, worsen traffic congestion and prolong taxi customers' in-vehicle travel times. This LOS standard can be applied together with other customer waiting time and taxi travel time prediction models to serve as a valuable reference to policymakers for establishing effective and appropriate transport policies to regulate taxi operations.

6. Conclusion

This paper proposes an alternative methodology to review the service quality of urban taxis and develops an LOS standard for taxi customers. A customer satisfaction survey was conducted to interview 1008 respondents in Hong Kong. The respondents were either taxi customers at taxi stands or pedestrians on streets who had taken taxis recently in the past three months. The interviewees were invited to provide satisfaction scores for ten selected service aspects and the score for the overall service performance, as well as to rank the important aspects. We develop an enhanced linear regression model to implicitly derive the importance of each of the service aspects to influence the overall service performance. The findings of the importance-satisfaction analysis suggest how service quality improvements should be prioritized. The highest priority should be given to improving the difficulty of hailing taxis on streets, waiting time required for a taxi, the attitude of taxi drivers, and the professionalism of taxi drivers. We further propose a six-level LOS standard for urban taxi customers. We determine this standard based on the numerical score estimated from the enhanced linear regression model, suggest an LOS threshold scheme for converting the LOS score to a letter grade. For the policy implications to enhance the taxi service quality, it is suggested to take appropriate enforcement actions against hire refusal, allow taxi picking up and dropping off at restricted zones when the impact to the local traffic is minimal, introduce a peak hour surcharge to suppress passenger demand for a shorter waiting time, encourage the taxi trade proactively improving the quality of taxi services, and explore the possibility of providing luxury taxi services.

A follow-up study is recommended to incorporate the LOS threshold scheme with other customer waiting time and taxi travel time prediction models to determine the appropriate taxi fleet size for offering reasonable service quality to taxi customers. For ongoing monitoring of taxi service quality, it is recommended to conduct annual customer satisfaction surveys and update taxi customers' perceptions of the

associated service aspects regularly.

Acknowledgments

This research was jointly supported by a grant from the Research Grants Council of the Hong Kong Special Administrative Region, China (HKU 17201217), a grant (201611159067) from the University Research Council, Aga Khan University, a Research Postgraduate Studentship from the University of Hong Kong, and a grant from National Natural Science Foundation of China (71271183). The authors wish to thank Snike Mi ZHOU, a student of Civil Engineering Department, The University of Hong Kong, for his assistance with data collection and analysis. The authors are grateful to the two reviewers for their constructive comments.

References

Abalo, J., Varela, J., Manzano, V., 2007. Importance values for importance-performance analysis: a formulation for spreading out values derived from preference rankings. J. Bus. Res. 60, 115–121.
Alonso, B., Barreda, R., dell'Olio, L., Ibeas, A., 2018. Modeling user perception of taxi service quality. Transport Pol. 63, 157–164.
Arnott, R., 1996. Taxi travel should be subsidized. J. Urban Econ. 40 (3), 316–333.
Correia, A.R., Wirasinghe, S.C., Barros, A.G., 2008. Overall level of service measures for airport passenger terminals. Transport. Res. Part A 42 (2), 330–346.
Chen, K.S., Chen, H.T., 2014. Applying importance-performance analysis with simple regression model and priority indices to assess hotels' service performance. J. Test. Eval. 42 (2), 455–466.
Chen, S.H., Yang, C.C., Lin, W.T., Yeh, T.M., 2007. Service quality attributes determine improvement priority. TQM Mag. 19 (2), 162–175.
Chiou, Y.C., Chen, Y.H., 2012. Service quality effects on air passenger intentions: a service chain perspective. Transportmetrica 8 (6), 406–426.
Dachyar, M., Rusydina, A., 2015. Measuring customer satisfaction and its relationship towards taxi's service quality around Capital City Jakarta. Int. J. Eng. Technol. 16 (1), 24–27.
Das, S., Pandit, D., 2015. Determination of level-of-service scale values for quantitative bus transit service attributes based on user perception. Transportmetrica A 11 (1), 1–21.
de Oña, J., de Oña, R., Eboli, L., Forciniti, C., Mazzulla, G., 2016. Transit passengers' behavioural intentions: the influence of service quality and customer satisfaction. Transportmetrica A 12 (5), 385–421.
Del Castillo, J.M., Benitez, F.G., 2013. Determining a public transport satisfaction index from user surveys. Transportmetrica A 9 (8), 713–741.
Douglas, G.W., 1972. Price regulation and optimal service standards: the taxicab industry. J. Transport Econ. Pol. 6 (2), 116–127.
Eboli, L., Mazzulla, G., 2011. A methodology for evaluating transit service quality based on subjective and objective measures from the passenger's point of view. Transport Pol. 18 (1), 172–181.
He, F., Shen, Z.J.M., 2015. Modeling taxi services with smartphone-based e-hailing applications. Transport. Res. Part C 58, 93–106.
Hung, Y.H., Huang, M.L., Chen, K.S., 2003. Service quality evaluation by service quality performance matrix. Total Qual. Manag. 14 (1), 79–89.
Kurtulmuşoğlu, F.B., Pakdil, F., Atalay, K.D., 2016. Quality improvement strategies of highway bus service based on a fuzzy quality function deployment approach. Transportmetrica A 12 (2), 175–202.
Lai, W.T., Chen, C.F., 2011. Behavioral intentions of public transit passengers – the roles of service quality, perceived value, satisfaction and involvement. Transport Pol. 18 (2), 318–325.
Lambert, D.M., Sharma, A., 1990. A customer-based competitive analysis for logistics decisions. Int. J. Phys. Distrib. Logist. Manag. 20 (1), 17–24.
Leng, B., Du, H., Wang, J., Li, L., Xiong, Z., 2016. Analysis of taxi drivers' behaviors within a battle between two taxi apps. IEEE Trans. Intell. Transport. Syst. 17 (1), 296–300.
Li, Q., Song, W., 2011. Service quality evaluation model for taxi industry based on entropy weight and TOPSIS method. In: Proceedings of the International Conference on Machine Learning and Cybermetrics, vol 3. pp. 1043–4047.
Loo, B.P.Y., Leung, B.S.Y., Wong, S.C., Yang, H., 2007. Taxi license premiums in Hong Kong: can their fluctuations be explained by taxi as a mode of public transport? Int. J. Sustain. Transport. 1 (4), 249–266.
Long, J., Szeto, W.Y., Du, J., Wong, R.C.P., 2017. A dynamic taxi traffic assignment model: a two-level continuum transportation system approach. Transport. Res. Part B 100, 222–254.
Lu, S., Chang, Y.H., 2014. Effects of service quality and customer satisfaction on customer loyalty in high-speed rail services in Taiwan. Transportmetrica A 10 (10), 917–945.
Matzler, K., Sauerwein, E., Heischmidt, K., 2003. Importance-performance analysis revisited: the role of the factor structure of customer satisfaction. Serv. Ind. J. 23 (2), 112–129.
Moore, A.T., Balaker, T., 2006. Do economists reach a conclusion on taxi deregulation? Econ. J. Watch 3 (1), 109–132.
Olawole, M.O., Aloba, O., 2014. Mobility characteristics of the elderly and their associated level of satisfaction with transport services in Osogbo, Southwestern Nigeria. Transport Pol. 35, 105–116.
Rose, J.M., Hensher, D.A., 2014. Demand for taxi services: New elasticity evidence for a neglected mode. Transportation 41 (4), 717–743.
Sampson, S.E., Showalter, M.J., 1999. The performance-importance response function: observations and implications. Serv. Ind. J. 19 (3), 1–25.
Schaller, B., 2007. Entry control in taxi regulation: implications of US and Canadian experience for taxi regulation and deregulation. Transport Pol. 14 (6), 490–506.
Shaaban, K., Kim, I., 2016. Assessment of the taxi service in Doha. Transport. Res. Part A 88, 223–235.
Tam, M.L., Lam, W.H.K., Lo, H.P., 2010. Incorporating passenger perceived service quality in airport ground access mode choice model. Transportmetrica 6 (1), 3–17.
Techarattanased, N., 2015. Service quality and consumer behavior on metered taxi services. Int. J. Econ. Manag. Eng. 9 (12), 4235–4239.
Transportation Research Board of the National Academies, 1999. TRCP Report 47: a Handbook for Measuring Customer Satisfaction and Service Quality. Washington, D.C., United States.
Transportation Research Board of the National Academies, 2008. NCHRP Report 616: Multimodal Level of Service Analysis for Urban Streets. Washington, D.C., United States.
Transport Department, 1986–2009. The Level of Taxi Services. TTSD Publication Series, Hong Kong SAR Government.
Wong, S.C., Yang, H., 1998. Network model of urban taxi services: improved algorithm. Transport. Res. Rec. 1623, 27–30.
Wong, K.I., Wong, S.C., Bell, M.G.H., Yang, H., 2005. Modeling the bilateral micro-searching behavior for urban taxi services using the absorbing Markov chain approach. J. Adv. Transport. 39 (1), 81–104.
Wong, K.I., Wong, S.C., Yang, H., 2001. Modeling urban taxi services in congested road networks with elastic demand. Transport. Res. Part B 35 (9), 819–842.
Wong, K.I., Wong, S.C., Yang, H., Tong, C.O., 2002. A sensitivity-based solution algorithm for the network model of urban taxi services. In: Taylor, M.A.P. (Ed.), Proceedings of the 15th International Symposium on Transportation and Traffic Theory. Elsevier Science, pp. 23–42.
Wong, K.I., Wong, S.C., Yang, H., Wu, J.H., 2008. Modeling urban taxi services with multiple user classes and vehicle modes. Transport. Res. Part B 42, 985–1007.
Wong, R.C.P., Szeto, W.Y., Wong, S.C., Yang, H., 2014a. Modelling multi-period taxi customer-searching behaviour. Transportmetrica B 2 (1), 40–59.
Wong, R.C.P., Szeto, W.Y., Wong, S.C., 2014b. Bi-level decisions of vacant taxi drivers traveling towards taxi stands in customer-search: modeling methodology and policy implications. Transport Pol. 33, 73–81.
Wong, R.C.P., Szeto, W.Y., Wong, S.C., 2014c. A cell-based logit-opportunity taxi customer-search model. Transport. Res. Part C 48, 84–96.
Wong, R.C.P., Szeto, W.Y., Wong, S.C., 2015a. A two-stage approach to modeling vacant taxi movements. Transport. Res. Part C 59, 147–163.
Wong, R.C.P., Szeto, W.Y., Wong, S.C., 2015b. Behavior of taxi customers in hailing vacant taxis in urban areas: a nested logit model for policy analysis. J. Adv. Transport. 49 (8), 867–883.
Wong, R.C.P., Szeto, W.Y., Yang, L., Li, Y.C., Wong, S.C., 2017. Elderly users' level of satisfaction with public transport services in a high-density and transit-oriented city. J. Transport Health 7, 209–217.
Xu, J., Wong, S.C., Yang, H., Tong, C.O., 1999. Modeling the level of urban taxi services using a neural network. ASCE J. Transp. Eng. 125 (3), 216–223.
Yao, Z.G., Ding, X.D., 2011. Measuring passenger's perceptions of taxi service quality with weighted SERVPERF. Appl. Mech. Mater. 97–98, 1181–1184.
Yang, H., Lau, Y.W., Wong, S.C., Lo, H.K., 2000. A macroscopic taxi model for customer demand taxi utilization and level of services. Transportation 27 (3), 317–340.
Yang, H., Leung, C.W.Y., Wong, S.C., Bell, M.G.H., 2010. Equilibria of bilateral taxi-customer searching and meeting on networks. Transport. Res. Part B 44 (8–9), 1067–1083.
Yang, H., Wong, S.C., 1998. A network model of urban taxi services. Transport. Res. Part B 32 (4), 235–246.
Yang, H., Wong, K.I., Wong, S.C., 2001. Modeling urban taxi services in road networks: progress, problem and prospect. J. Adv. Transport. 35 (3), 237–258.
Yang, H., Yang, T., 2011. Equilibrium properties of taxi markets with search frictions. Transport. Res. Part B 45, 696–713.
Yang, H., Ye, M., Tang, W.H.C., Wong, S.C., 2005. A multi-period dynamic model of taxi services with endogenous service intensity. Oper. Res. 53, 501–515.
Yang, T., Yang, H., Wong, S.C., 2012. Taxi services with search frictions and congestion externalities. J. Adv. Transport. 48, 575–587.
Yang, T., Yang, H., Wong, S.C., Sze, N.N., 2014. Returns to scale in the production of taxi services: an empirical analysis. Transportmetrica A 10 (9), 775–790.
Zhang, S., Tang, J., Wang, H., Wang, Y., An, S., 2017. Revealing intra-urban travel patterns and service ranges from taxi trajectories. J. Transport Geogr. 61, 72–86.